Top Dilepton Cross-Section Measurement -BLESSING-

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on behalf of

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with *Top Dilepton Working Group*

Presentation Overview

- Nothing Changed Since the Preblessing except
  - Documentation
  - Performed cross-checks
  - B-tags Estimates
- Answer to questions raised during Preblessing Talk
- Acceptance and Backgrounds
- Cross Section Result
- More Cross-Checks
  - b-tags
- PR Plots for Blessing

Documentation

- CDF Notes:
  - CDF6830 "Measurement of the tt xsection with dileptons"
  - CDF6742 "A 2nd Determination of the Fake Background"
  - CDF6590 "Acceptance and Background Systematics"
- Summer'03:
  - CDF6517 "Adding CMIO muons to the Top Dilepton xsection"
  - CDF6579 "Optimization studies for the Top Dilepton xsection"
  - CDF6591 "Determination of DY background – Summer'03"
  - CDF6592 "Fake Lepton Backgrounds for the Summer'03"
  - CDF6588 "A measurement of the tt xsection – Summer'03 "
- Q&A web page in place
  - http://www-cdf.fnal.gov/internal/physics/top/run2dil/iteration3/doc.html
- Previous talks at this meeting
  - Mircea Coca, "Full Status Report", 29-JAN-2004
  - Andy Hocker, "Dilepton Cross Section Update", 08-JAN-2004
  - Monica Tecchio, "Top Dilepton Cross-Section-Preblessing", 05-FEB-2004

History of the Analysis

- Blessed with 72 pb^{-1} in Spring'03

  using tight-tight dilepton categories
- Performed various optimizations for Summer'03
  - doubled the acceptance
  - blessed result with 126pb^{-1}
- This is the third iteration
  - incorporating the lessons from the previous two

  to keep a high purity analysis
    - S/B = 3.5
  - use the full dataset available until September 2003 shutdown: 193 pb^{-1}

Questions from Preblessing I

- Q: How do you know you don't have real leptons in the jet samples?
- A: We reject the events with obvious high-P_T “real” leptons
  - W’s by requiring MET < 20 GeV
  - Z’s if there are two tight leptons in the mass window
  - Contamination is smaller in case of muons
    - Only a W+1j could make into the inclusive QCD samples
  - Changing slightly the MET cut: 15, 20 or 25 GeV does not change the fake estimate
  - JET100 fake rates are consistent with JET50 fake rates
  - We looked at the fake rates in a b-enriched sample
    - They are consistent with fake rates from generic jets

Questions from Preblessing II

- Q: Why is it better to use CdfEmObjects and min-I tracks than generic jets?
- A: We estimated for the Summer 2003 the fake background in both ways
  - Found good agreement (See CDF6742)
  - An electron is just a small part of a jet
    - E_T(jet) $\neq E_T$(fake lepton from jet), so it is not straight forward to do E_T parameterizations
    - A 100 GeV jet could fake a 20 or a 50 GeV lepton, so the fake rate might be JET sample dependent, gluon vs quark jet dependent, etc
    - Good agreement between predicted and observed # of fakes in various jet samples

Questions from Preblessing III

- Q: The fact that you see agreement in the j100 sample, despite 300% uncertainty.... luck?
- N: Looked back and found that the binning used was too fine
  - Not what we used for fake estimate
  - Using the coarser binning we get

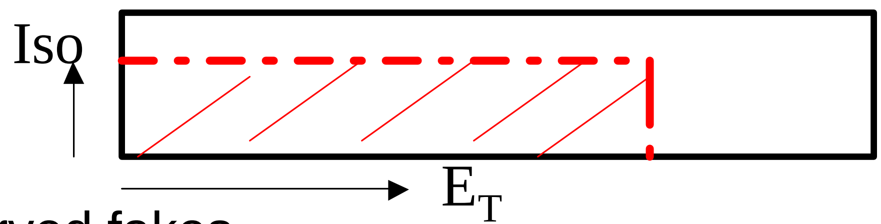
NCEM

	pred	obs
J20	37 +/- 7	34 +/- 6
J70	74 +/- 40	63 +/- 8
J100	63 +/- 190	67 +/- 8

	pred	obs
J20	32 +/- 3	34 +/- 6
J70	85 +/- 15	63 +/- 8
J100	**77 +/- 70**	67 +/- 8

Questions from Preblessing IV

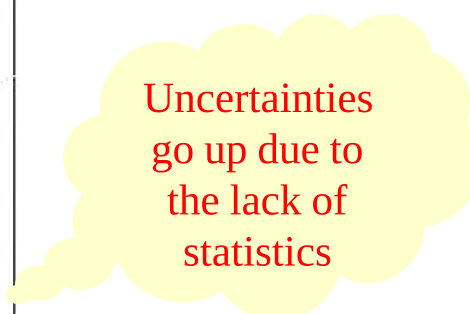
- Q: So then can you do a meaningful test by restricting the test to lower-E_T jets in the j100 sample?
- A: Yes, good idea.



We vary MAX_{Iso} and MAX_{ET} and look at predicted vs observed fakes in $(20, MAX_{ET}) \times (0.1, MAX_{Iso})$

MAX E_T	MAX IsoFr	Observed	Predicted
40.0	0.7	28.00 ± 5.29	31.83 ± 2.15
40.0	1.5	39.00 ± 6.24	44.80 ± 3.14
50.0	2.1	49.00 ± 7.00	60.36 ± 5.35
50.0	0.7	34.00 ± 5.83	43.87 ± 2.96
60.0	2.1	55.00 ± 7.42	65.06 ± 11.38
60.0	0.3	25.00 ± 5.00	19.84 ± 2.27
80.0	2.5	65.00 ± 8.06	77.00 ± 48.37
120.0	2.5	67.00 ± 8.19	77.00 ± 61.96
120.0	1.5	64.00 ± 8.00	72.49 ± 56.92

NCEM



Questions from Preblessing V

- Q: Don't you have to know the generic jet -> fakeable jet rate?
- A: No, because the fake rates determined per fakeable jet are only applied to W+fakeable jet(s) events.

- Q: What do you predict/observe in terms of SS events?
- A: Using Jet50 fake rates and W+multijets we get

	0 jet	1 jet	≥2 jet
SS predicted	2.3 ± 0.5	1.8 ± 0.4	0.9 ± 0.2
SS PHX charge fake	0.61 ± 0.25	0.26 ± 0.1	0.08 ± 0.03
SS observed	3	2	0

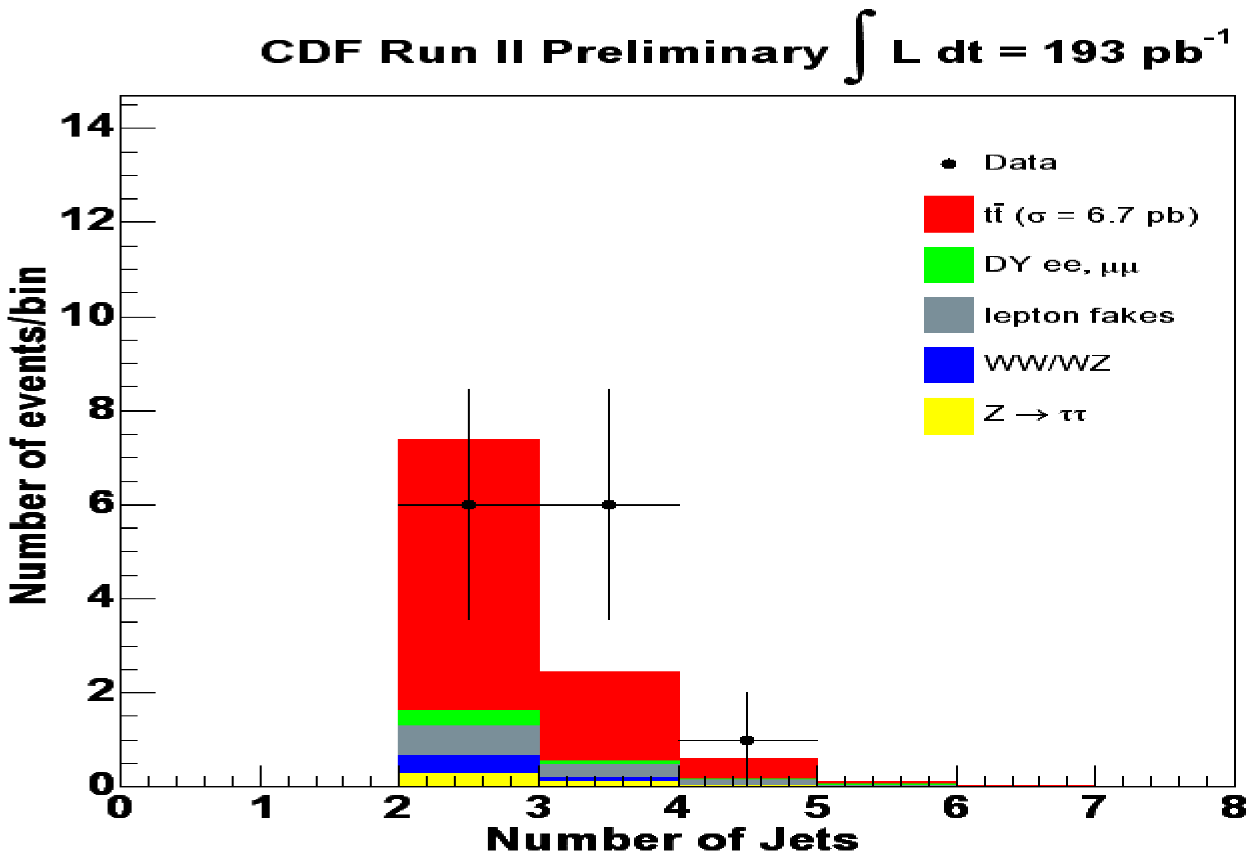
Questions from Preblessing VI

- Q: Why do all the Z cross sections come out low?
- A:They all have a common systematic of about 15 pb from the luminosity uncertainty.
  - Also the estimates agree with what other groups measured
    - Lepton+track group saw the same behavior

- Q:How many b-tags do you expect?
- A: This will be answered later in the talk…

Questions from Preblessing VII

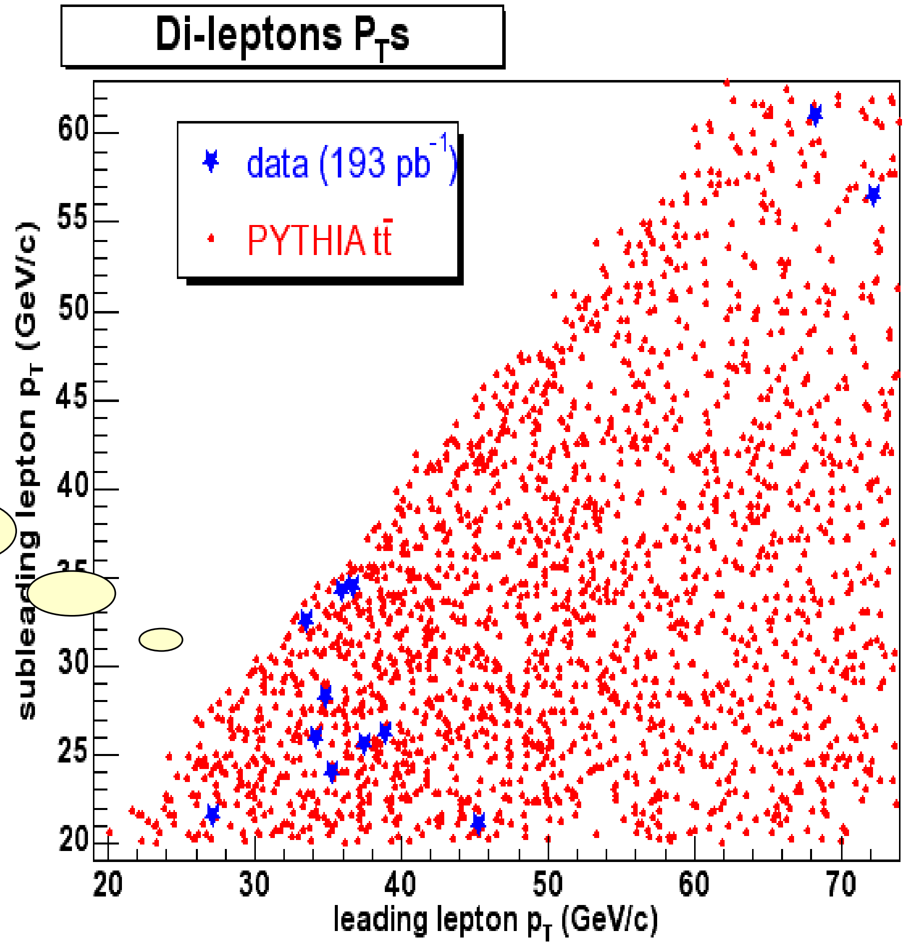
- Q: Awful lot of jets in your candidates, aren't there?
- A: Not quite! Still low statistics, but the agreement with Pythia is good.



Questions from Preblessing VIII

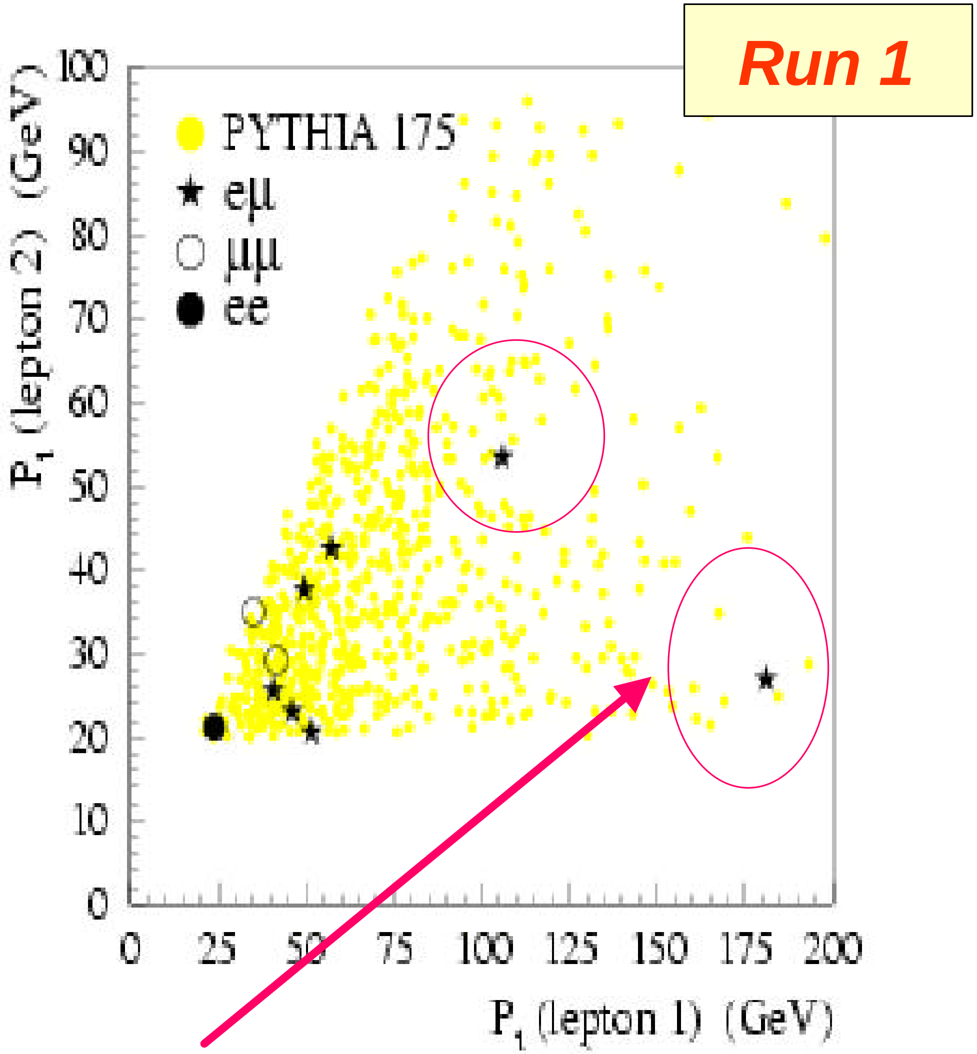
- Q: Exactly how are the lepton P_T's distributed in that lowest bin?
- A: Let's look at the data.

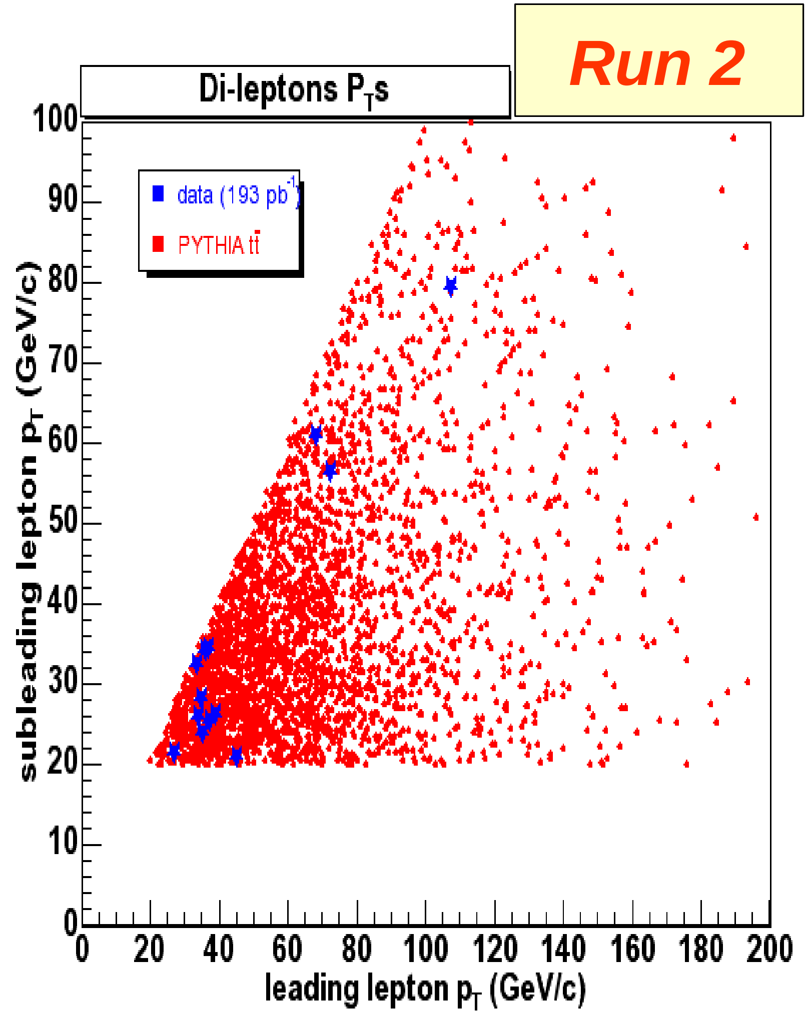
Leading lepton:
1 lepton $\in$ (20, 30) GeV
None $\in$ (30, 35) GeV
8 leptons $\in$ (35, 40) GeV



- So not all soft…

Got the Run I memory ?





- Large transverse momentum leptons in Run 1

Dilepton Categories

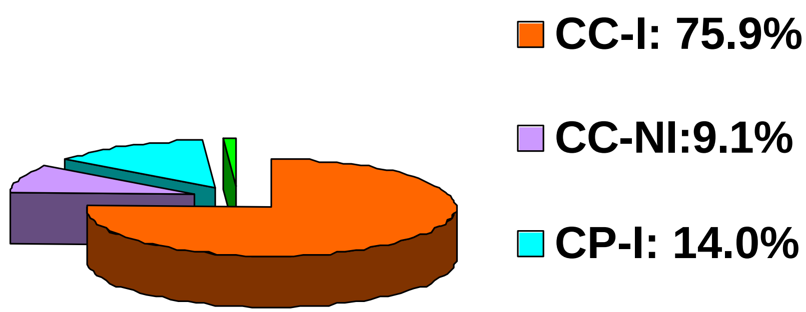
ee category: 22.2%	Trigger required
CEM – CEM	CEM_18
CEM – PHX	CEM_18
mm category: 23.5%	
CMUP – CMUP	CMUP_18
CMUP - CMIO/U/P	CMUP_18
CMX - CMIO/U/P	CMX_18
CMX - CMX	CMX_18
CMX - CMUP	CMX_18 || CMUP_18
em category: 54.3%	
CEM – CMUP	CEM_18 || CMUP_18
CEM - CMIO/U/P	CEM_18
CEM – CMX	CEM_18 || CMX_18
PHX – CMUP	CMUP_18
PHX – CMX	CMX_18
PHX - CMIO/U/P	MET_PEM

Red lepton types are the trigger leptons

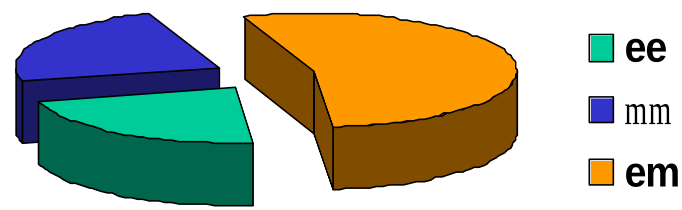
Only 3.2% of dileptons come on MET_PEM trigger

Signal Composition

By event topology



By lepton flavor



CC = central-central

CP = central-plug

I = isolated

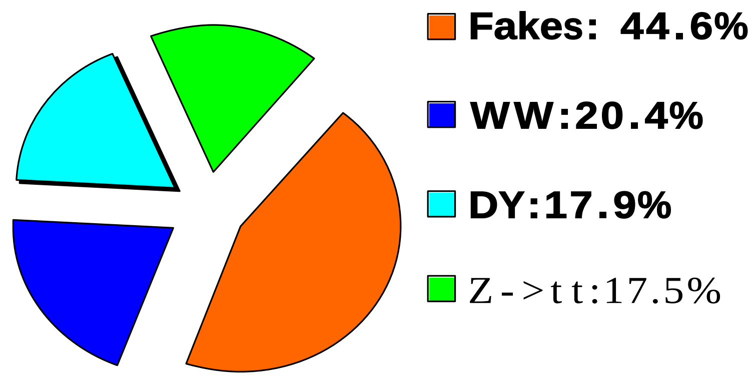
NI = non-isolated

ee: 22.2 %
μμ: 23.5 %
eμ: 54.3%

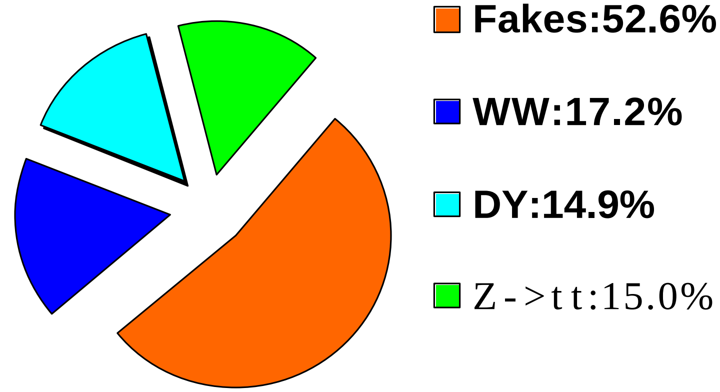
Backgrounds

- **Fakes:** estimated from $W+N_{jets}$ data sample using fake rates for each lepton type extracted from Jet50 sample
- **WW/WZ/ZZ:** estimated from Pythia Monte Carlo
- **Z->ee and Z->mm (DY):** estimated from data and Monte Carlo
- **Z->tt:** estimated from Pythia Monte Carlo and data (2 jet fraction).

After H_T and OS



Before H_T



Backgrounds- Systematic Uncertainties

For Blessing

Background	Source	Uncertainty (%)	% Error on the Xsec
Fakes	Method	31	3.3
	Different Jet Samples	9	
DY (ee, mm)	Method	100	4.1
	Jet energy scale (H_T)	20	
WW/WZ	MC Generator	36	1.7
	Jet energy scale	18	
Z ? tt	2-jet efficiency	10	0.4
	Jet energy scale	29	

If only source of systematics, they would contribute ±0.5 pb
(out of ±1.4 pb total for measured cross-section)

Signal Acceptance

- Raw acceptance using *ttopei* Pythia
  - restricting to MC top dilepton events at HEPG level events
  - with OBSV $|z_v| < 60$ cm:

$$0.813 \pm 0.014\%$$

- Raw efficiency is corrected for:
  - OBSV $|z_v| < 60$ cm efficiency: (0.951 ± 0.005) (CDF 6660)
  - Lepton ID Scale Factor, one for each lepton type
  - Muon Reconstruction Scale Factor
  - Trigger Efficiencies
  - PHX Charge Fake Rate from Data (13%)
- Total effect is to decrease the raw efficiency by ~ 15%

Acceptance Corrections

- Use blessed CDF numbers (except the ones in red)

lepton type	lepton-ID SF	μ-rec SF	ε^{trig}
CEM	0.965 ± 0.006	NA	0.966 ± 0.001
NICEM	0.96 ± 0.11	NA	NA
PHX	0.87 ± 0.01	NA	0.88 ± 0.03
CMUP	0.94 ± 0.01	0.927 ± 0.010	0.890 ± 0.009
CMX	1.015 ± 0.007	0.992 ± 0.011	0.966 ± 0.007
CMU	0.993 ± 0.013	0.989 ± 0.021	NA
CMP	0.983 ± 0.011	0.920 ± 0.016	NA
NICMALL	0.986 ± 0.041	as for Iso	NA

Z→*ll* Cross Sections

- We measure the Z cross-section in all of the di-lepton categories used in our analysis
  - A way to validate acceptance correction factors, data quality and luminosity
  - Use version 4 of DQM good run list
  - Include I/NI loose lepton
  - Errors are from statistics and luminosity
  - They all agree with NLLO theoretical prediction of

    252 ± 9 pb

Dilepton Category	s ×B(Z? l l) (pb) ± stat ± syst	*L* (pb^{-1})
CEM-CEM	235 ± 4 ± 15	162
CEM-PHX	240 ± 4 ± 15	162
CMUP-CMUP	234 ± 8 ± 17	193
CMUP-CMIO/U/P	244 ± 6 ± 17	193
CMX-CMX	225 ± 14 ± 16	175
CMX-CMIO/U/P	247 ± 9 ± 16	175
CMUP-CMX	247 ± 8 ± 16	175

Acceptance Systematic Uncertainties

For Blessing

Source	Uncertainty (%)
Lepton ID SF	5.0
Jet Energy Scale	4.7
ISR/FSR	1.7
PDF's	11.6*
MC Generators (Pythia vs. Herwig)	5.5
Total	**14**

- If only source of systematics, they would contribute ±1.2 pb (out of ±1.4 pb total for measured cross-section)

Dataset

- High-P_T inclusive lepton datasets, 4.11.1 REMAKE
- Plug dataset (bpel08/09), stripped on L3 MET_PEM, 4.11.1 “REMAKE”
- PES alignment corrections done when ntuplizing data
- Use version 4 of DQM good run lists
  - Bad CSL and SVX beam line runs excluded by hand
- We require good CMX runs for CMX dilepton categories and good SVX runs for PHX categories:
  - CEM/CMUP: 193 pb^{-1}
  - CEM/CMUP and CMX: 175 pb^{-1}
  - CEM/CMUP and SVX: 162 pb^{-1}
  - CEM/CMUP and SVX and CMX: 150 pb^{-1}
- Effect of folding different luminosities with dilepton category is equivalent to a further 5% decrease in signal acceptance

Results

- Cross-check our background predictions in regions with no top signal

Good agreement in N=0j and N=1j bins

SIGNAL REGION

For Blessing

Source	N jets 0j	1j	$\geq$ 2j	H_T, OS
WW/WZ	12.1 ± 4.9	3.2 ± 1.3	0.81 ± 0.33	0.49 ± 0.21
Drell-Yan	4.4 ± 2.0	2.2 ± 1.1	0.7 ± 0.4	0.43 ± 0.44
$Z \rightarrow \tau\tau$	0.19 ± 0.06	0.86 ± 0.26	0.69 ± 0.21	0.42 ± 0.13
Fakes	5.53 ± 1.14	4.35 ± 0.90	2.47 ± 0.52	1.07 ± 0.35
Total Background	22.2 ± 6.7	10.6 ± 2.8	4.7 ± 1.0	2.4 ± 0.7
$t\bar{t}$ ($\sigma = 6.7$ pb)	0.1 ± 0.0	1.4 ± 0.2	8.7 ± 1.2	8.2 ± 1.1
Total SM expectation	22.3 ± 6.7	12.0 ± 2.8	13.3 ± 1.7	10.6 ± 1.4
Run II data	19	11	14	13

Results per di-lepton flavor

For Blessing

CDF II Preliminary 193 pb^{-1}

Source	Events per 193 pb^{-1} after all cuts			
	ee	$\mu\mu$	eμ	$\ell\ell$
WW/WZ	0.15 ± 0.06	0.12 ± 0.05	0.22 ± 0.09	0.49 ± 0.21
Drell-Yan	0.36 ± 0.28	0.07 ± 0.34	-	0.43 ± 0.44
Z $\rightarrow \tau\tau$	0.09 ± 0.03	0.11 ± 0.03	0.22 ± 0.07	0.42 ± 0.13
Fakes	0.30 ± 0.10	0.15 ± 0.05	0.62 ± 0.22	1.07 ± 0.35
Total Background	0.9 ± 0.3	0.4 ± 0.4	1.1 ± 0.2	2.4 ± 0.7
$t\bar{t}$ ($\sigma = 6.7$ pb)	1.9 ± 0.3	1.8 ± 0.3	4.5 ± 0.6	8.2 ± 1.1
Total SM expectation	2.8 ± 0.4	2.3 ± 0.5	5.5 ± 0.7	10.6 ± 1.4
Run II data	1	3	9	13

- Signal / Background =3.5

Cross-Section Result

$$\sigma(t\bar{t}) = \frac{N_{obs} - N_{back}}{\varepsilon \times A \times \int L dt}$$

$$\varepsilon \times A \times \int L dt = (1.22 \pm 0.17)\, pb^{-1}$$

- **Winter'04 Top Dilepton Cross-Section** at m_t= 175 GeV:

$$\boxed{\sigma_{t\bar{t}} = 8.7^{+3.9}_{-2.6}(stat) \pm 1.4(syst) \pm 0.5(lumi)\ pb}$$

- Theoretical Prediction: (6.7±0.5) pb.
- Summer'03 Top Dilepton Cross-Section:

$$\boxed{\sigma_{t\bar{t}} = 7.6^{+3.8}_{-3.1}(stat)^{+1.5}_{-1.1}(syst)\ pb}$$

Candidate events

	Type	N_{JETS}	SecVtx Info	Trigger coming on
ee	CEM -CEM	3		CEM_18
mm	CMUP-CMX	2	2 btags	CMUP_18 && CMX_18
	CMUP-CMP	2	2 btags	CMUP_18
	CMX -CMX	3	1 btags	CMX_18
em	CEM -CMUP	2		CEM_18 && CMUP_18
	CEM -CMU	3	1 btag (on lowest Et jet)	CEM_18
	CEM -CMP	4	*bad SVX*	CEM_18
	CEM -CMX	2	2 btags	CEM_18 && CMX_18
	CEM -CMX	3	1 btag	CEM_18 && CMX_18
	CEM -CMX	3		CEM_18 && CMX_18
	CEM -CMIO	3		CEM_18
	PHX -CMUP	2		CMUP_18 && MET_PEM
	CMUP-NICEM	2	1 btag (away from NICEM!)	CMUP_18 && CEM_18

Expect 1 NI lepton event
Got 1

Expected/Observed b-tags

- $\varepsilon_{btag}^{evt} = F_{1b}\, e_{btag} S + F_{2b}\, 2^* e_{btag} S\,(1- e_{btag} S) + F_{2b}\, e^2_{btag} S^2$

$\varepsilon_{1\text{-}btag}^{evt}$ $\varepsilon_{2\text{-}btag}^{evt}$

CDF6585

S = data/MC b-tag scale factor

F_{1b}, F_{2b} = fraction of events with 1 or 2 taggable b-jets

ε_{btag} = b-tagging efficiency per jet (from MC)

	dilepton	l+jets
ε_{btag}	0.543 +/- 0.008	0.535+/-0.006
F_{1b}	0.364 +/- 0.009	0.395+/-0.005
F_{2b}	0.539 +/- 0.009	0.489+/-0.013

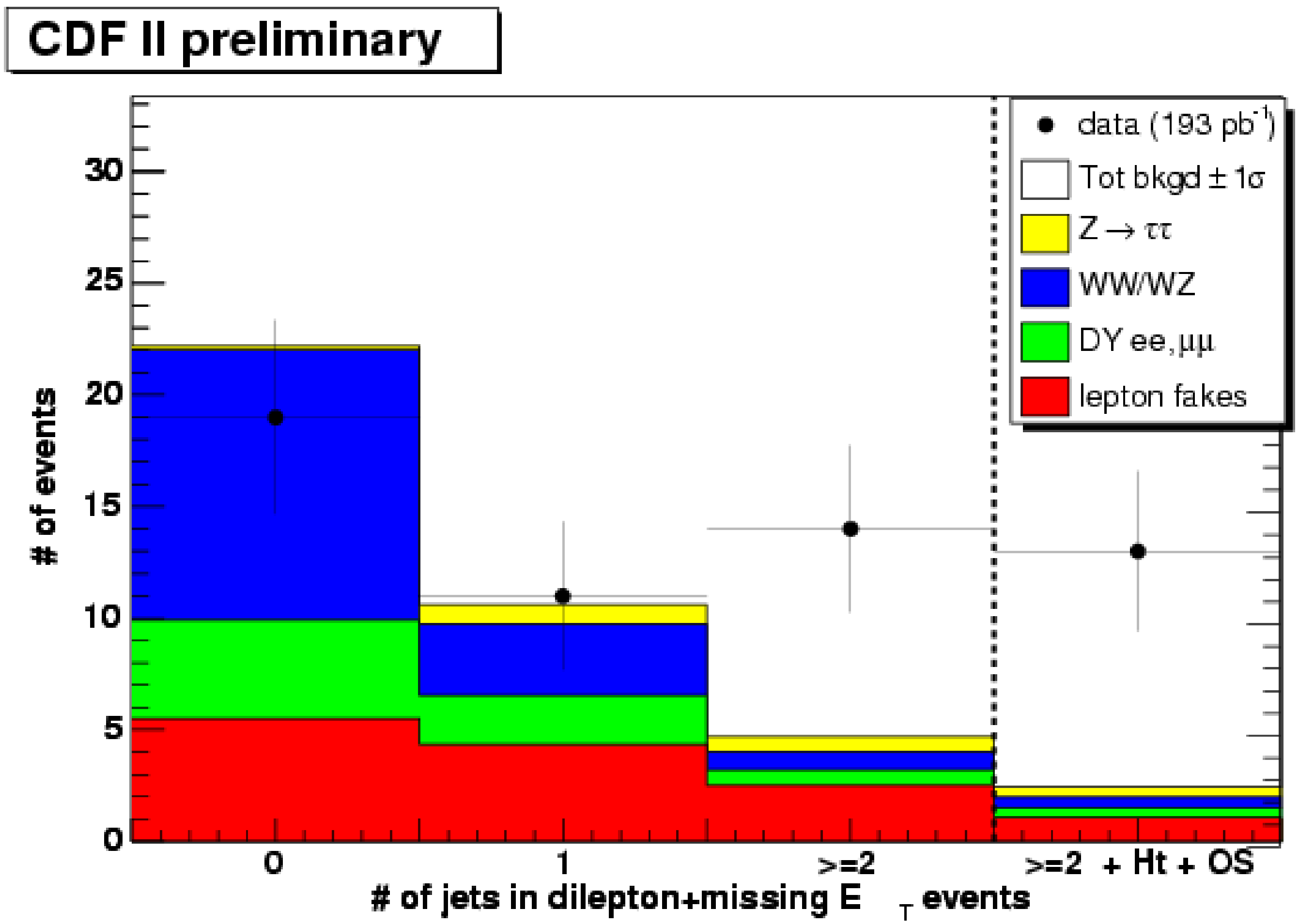
- ε_{btag}^{evt} = 0.560+/-0.168
- $\varepsilon_{1\text{-}btag}^{evt}$ = 0.442+/-0.125
- $\varepsilon_{2\text{-}btag}^{evt}$ = 0.118+/-0.038

For Blessing

	Observed	Predicted
# Tagged Events	7	5.9±1.8
# Single Tagged Events	4	4.6±1.3
# Double Tagged Events	3	1.3±0.5

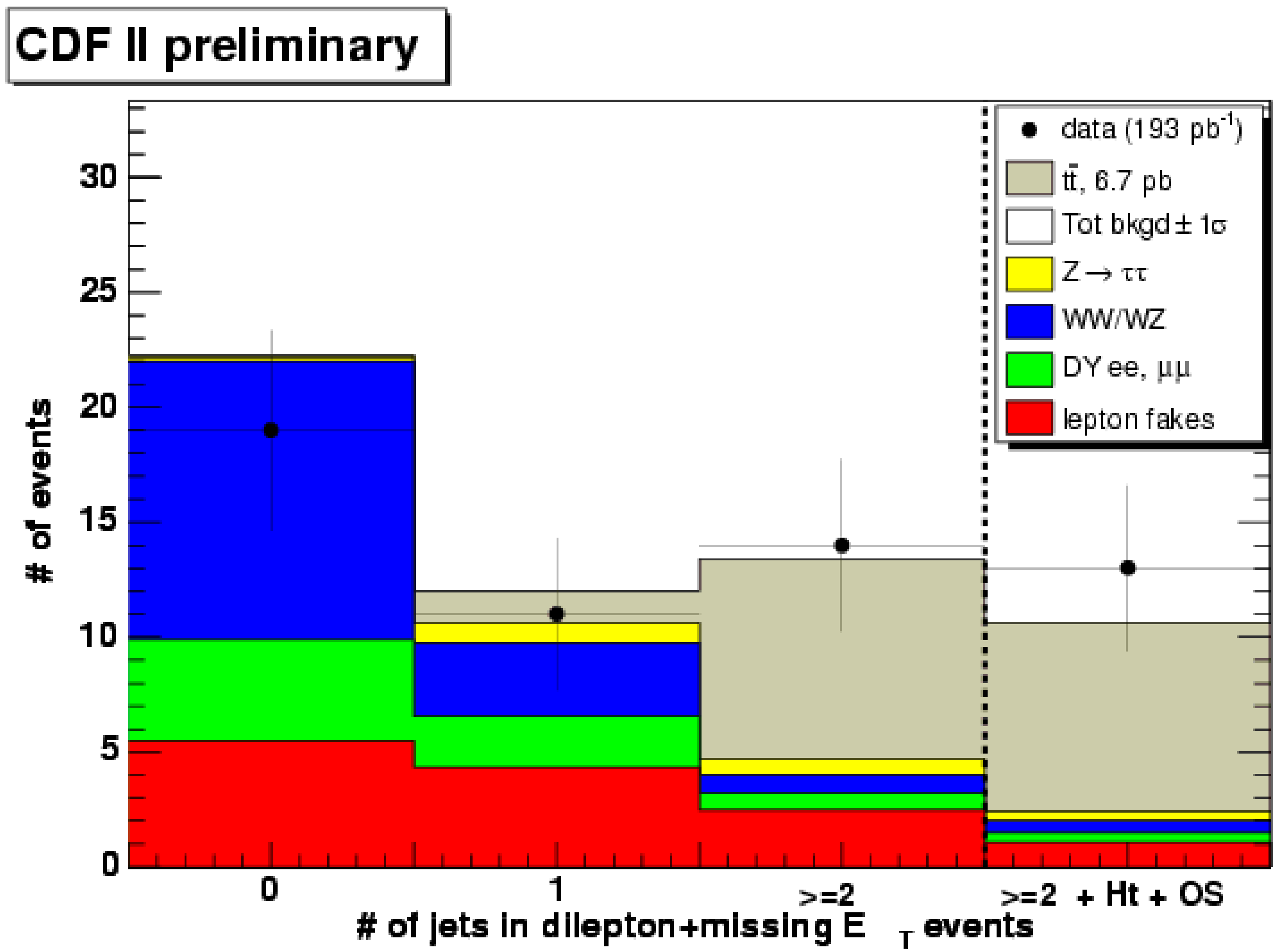
N_{JET} – *BG only*

For Blessing



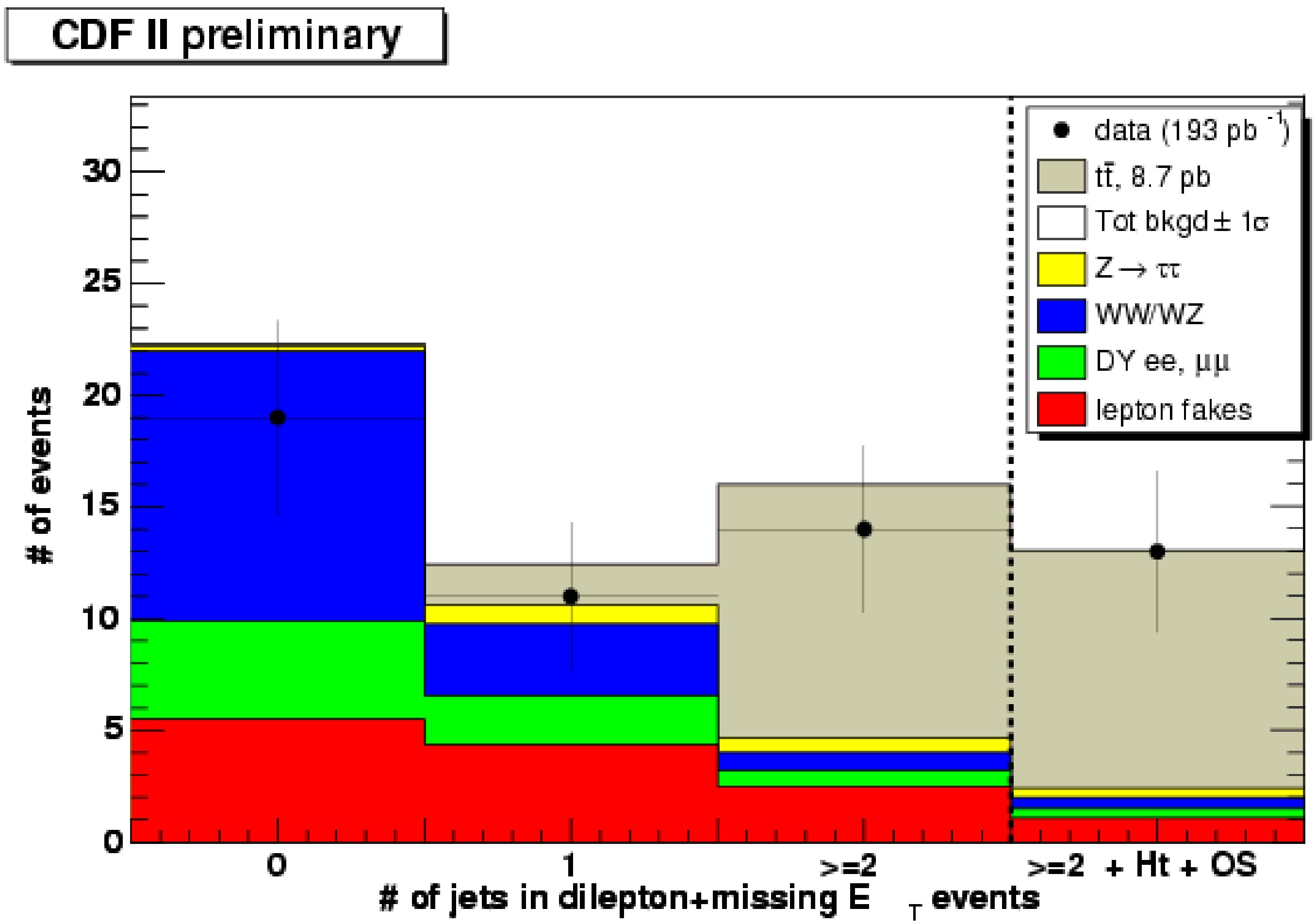
N_{JET} – BG+SIGNAL (6.7 pb)

For Blessing



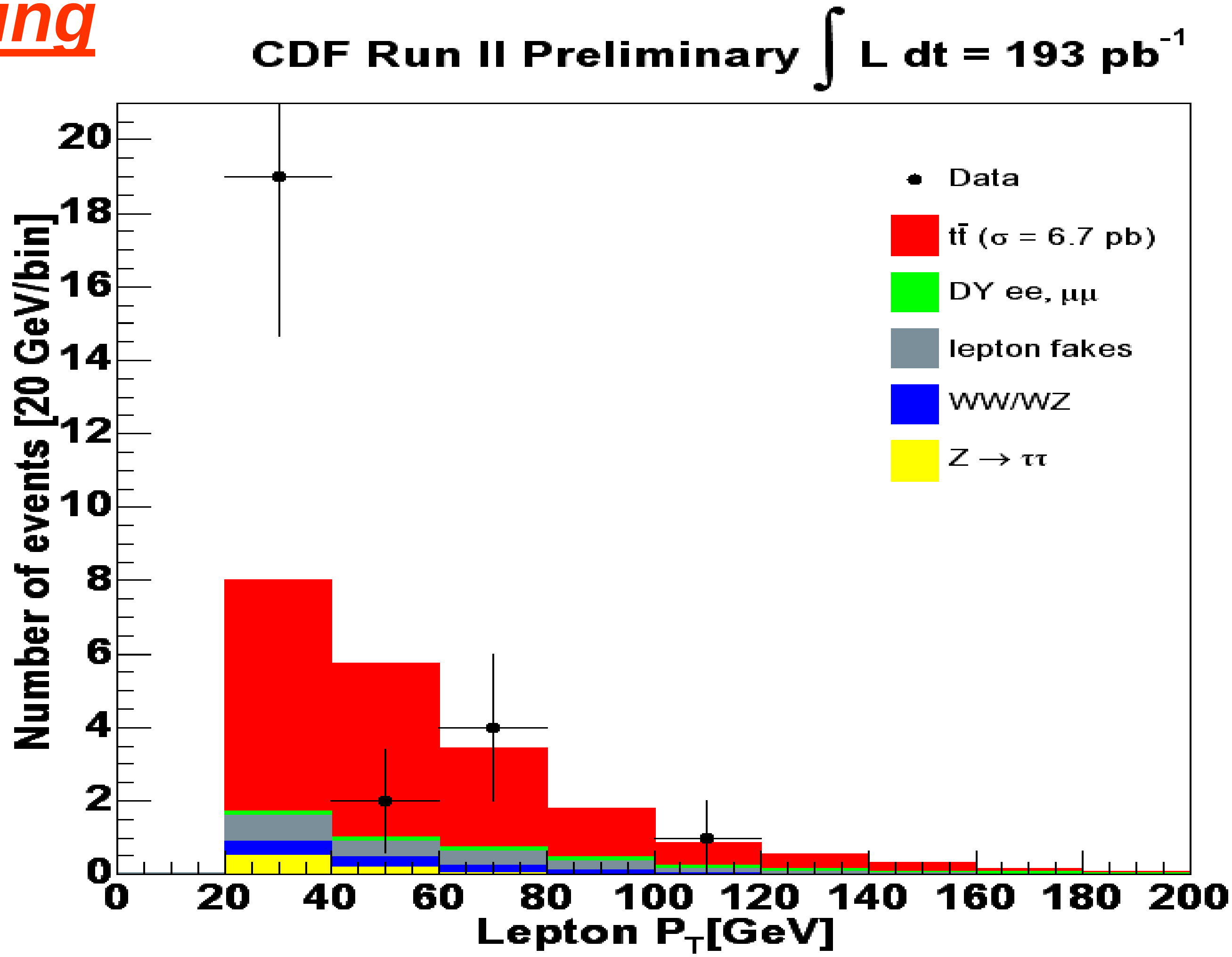
N_{JET} – *BG+SIGNAL (8.6 pb)*

For Blessing



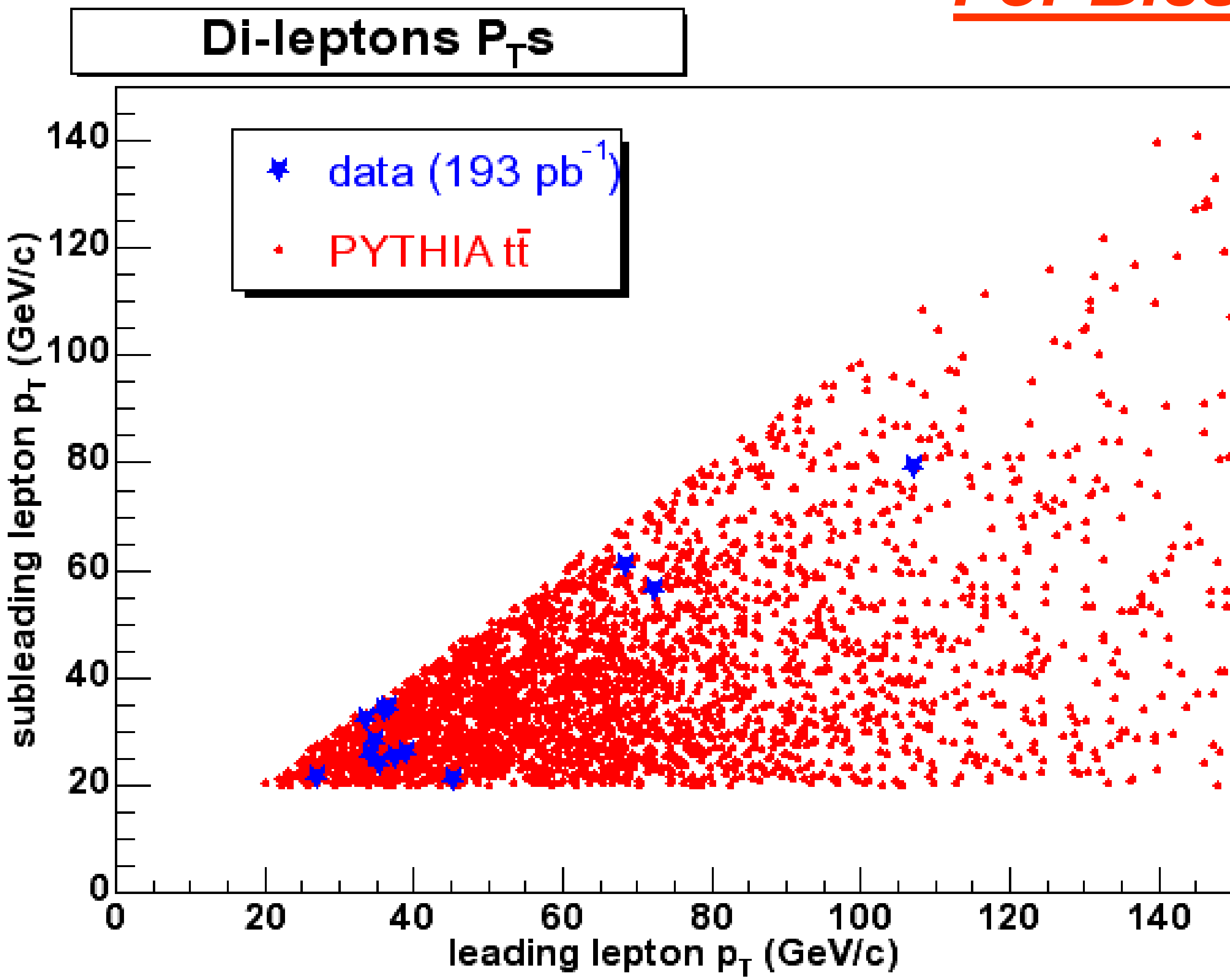
Lepton p_T – *BG+SIGNAL* (6.7 pb)

For Blessing



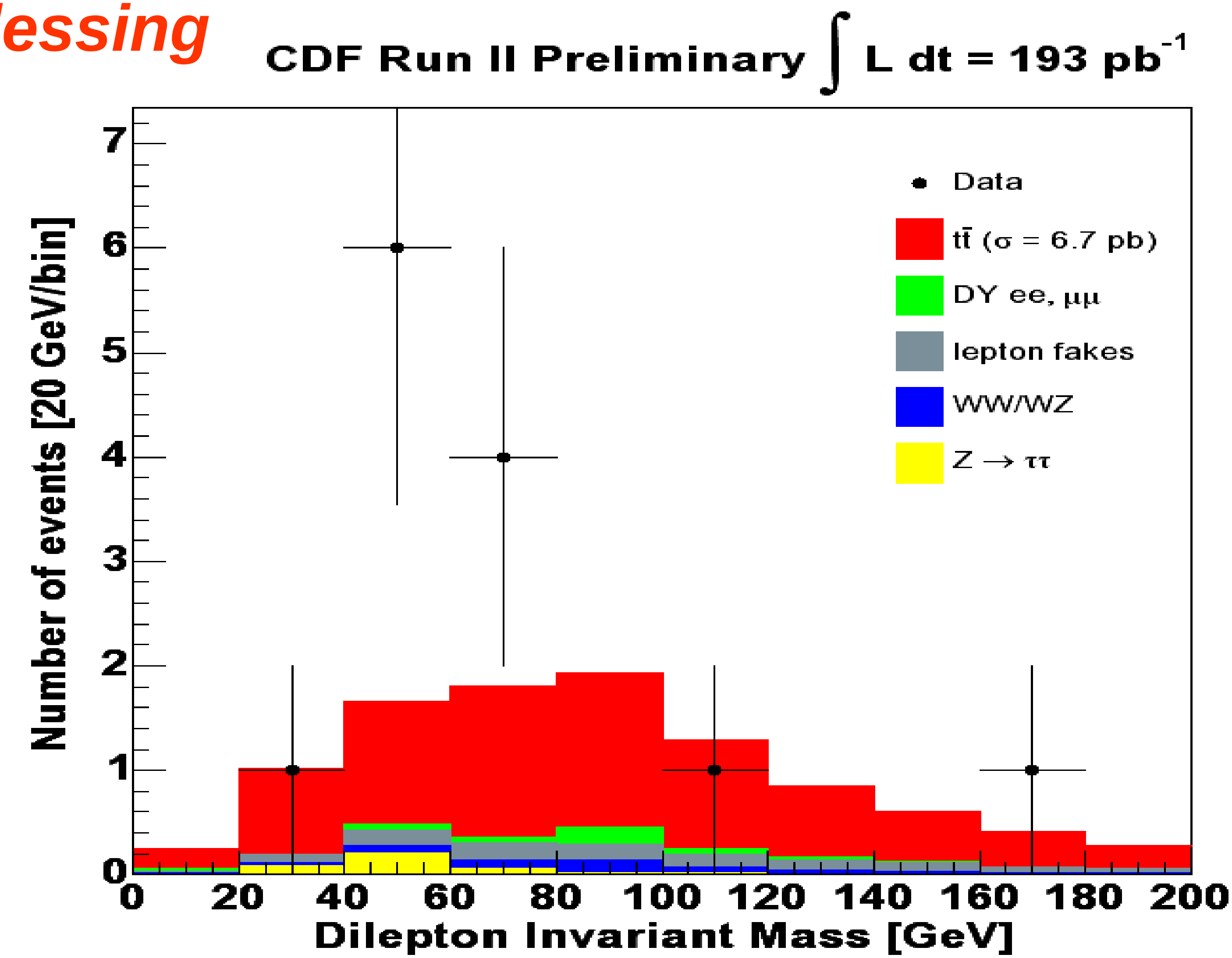
P_T(highest) vs P_T(2^{nd} highest)

For Blessing



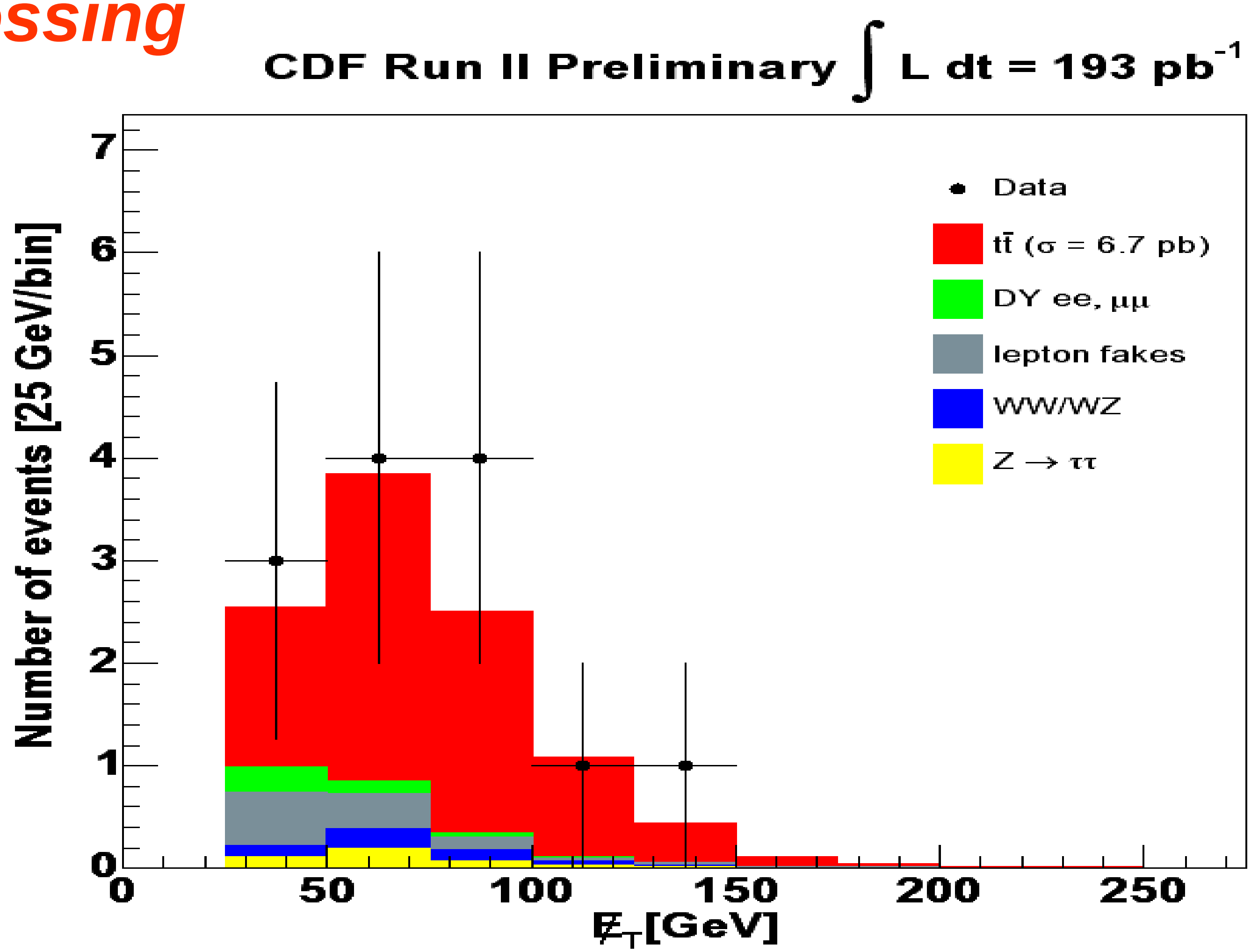
Di-lepton Mass – *BG+SIGNAL (6.7 pb)*

For Blessing



MET – *BG+SIGNAL (6.7pb)*

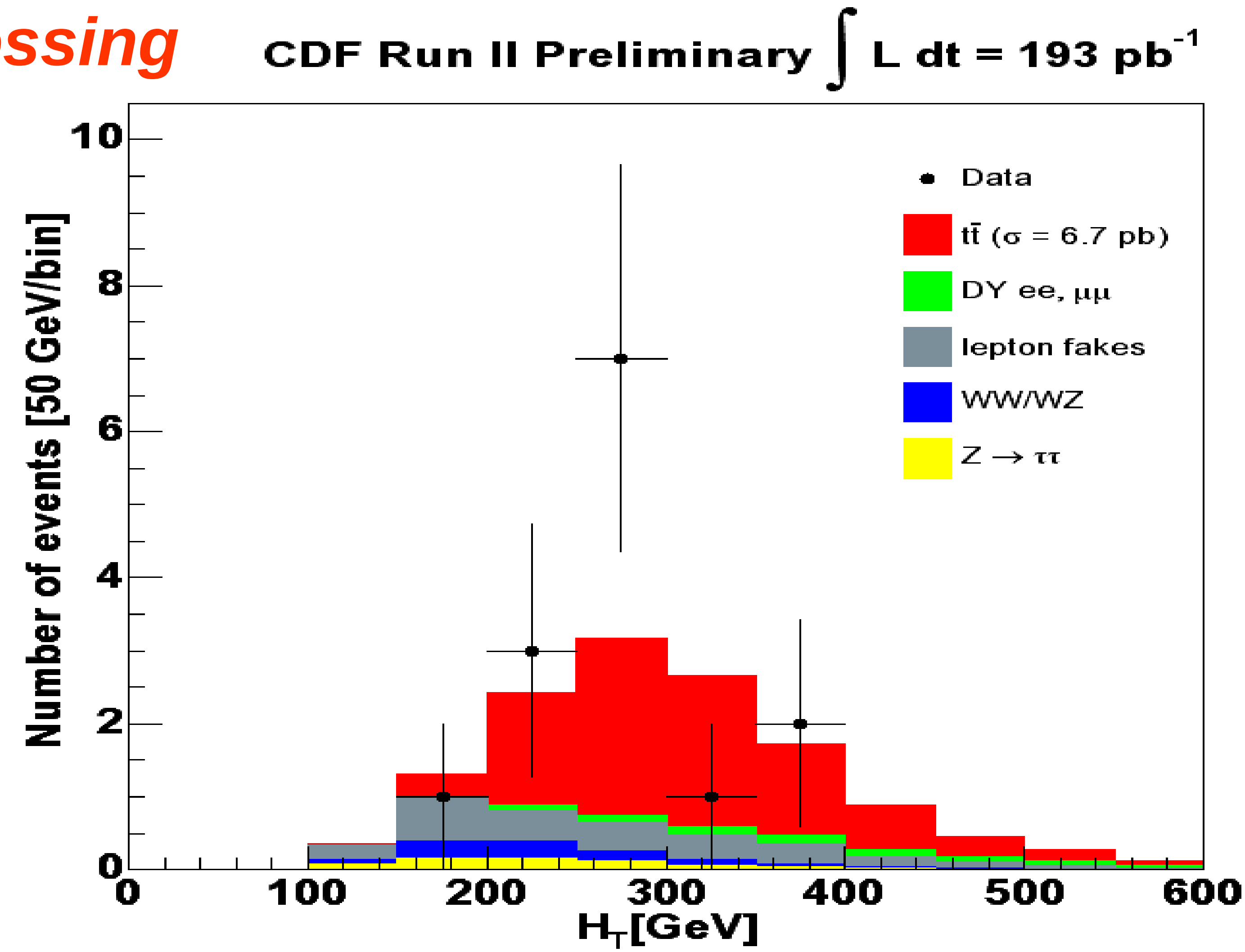
For Blessing



MET distribution for events passing all the cuts

H_T – BG+SIGNAL (6.7 pb)

For Blessing



H_T distribution for events with ≥2 jets, before H_T or OS cuts

Conclusions

- We measured top cross-section in dilepton channel in 193 pb^{-1} of data
  - a high purity selection: S:B = 3.5:1
- The result

$$\boxed{\sigma_{t\bar{t}} = 8.7^{+3.9}_{-2.6}(stat) \pm 1.4(syst) \pm 0.5(lumi)\ pb}$$

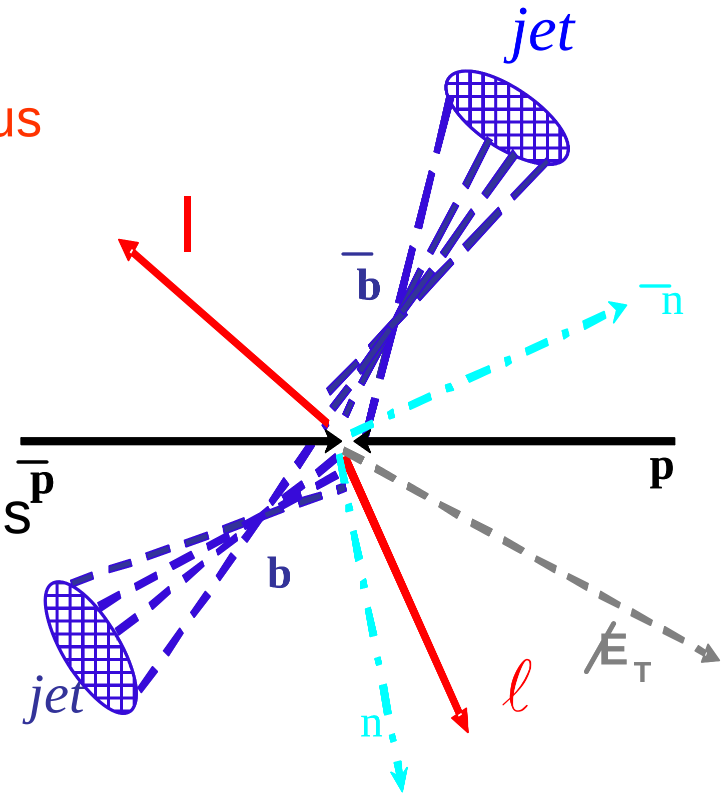
is consistent with SM predictions.

- We would like to move toward a publication
- We had a second meeting with GPs today

Backup Slides

Top Dilepton Topology

- 2 high-E_T, leptons (e, μ)
  - Sensitive only to leptonic decays of taus
  - Loose nonisolated leptons allowed
- Large missing energy E_T
  - Corrected for muons
    and tight L5 jets
- Z-mass region for same-flavour events
  - special treatment
- At least 2 jets with large E_T
  - Cone algorithm 0.4
  - Corrected E_T to L5, $|\eta|$ < 2.5
- Large transverse energy flow
  $H_T = \Sigma(E_T^{leptons}, E_T^{jets}, MET)$



Changes from Summer’03

- Revisited the lepton categories (See Andy’s Talk)
  - Excluded Non-PHX PEMs
    - Big bckgr source: half the fakes, 20% of total bckgr
    - Contributes about 5% to top acceptance
  - Excluded Plug-Plug categories
    - < 2% of top acceptance
    - Come in on MET_PEM trigger, which makes any data-driven DY determination very hard
- Cut on COT exit radius for CMX muons
- PHX $|\eta| < 2.0$ to reduce the charge fake
  - (Summer’03: $|\eta| < 2.5$)
- Updated the scale factors, trigger and reconstruction efficiencies

Event Selection

- $\geq$ 2 leptons, $p_T > 20$ GeV
  - At least one of which is TIGHT (CEM, CMUP, CMX or PHX)
  - At most one central lepton (except CMIO) can be nonisolated
- $\geq$ 2 jets, L5 corrected, $E_T > 15$ GeV
- MET > 25 GeV (corrected for muons, jets)
  - If MET < 50 GeV, $\Delta\phi$ (MET, nearest l or j) > 20 deg
- If 76 GeV < M_{ll} < 106 GeV and same-flavor,
  - jetSig > 8 (jetSig=MET/sqrt(Σ jet E_T projected on MET))
  - $\Delta\phi$ (MET, nearest l or j) > 10 deg
- $H_T > 200$ GeV ($H_T = \Sigma$(leps, jets, met))
- Opposite charge

DY background method 1

- Use data:
  - To measure the number of Z's inside the mass window
    - N_{MET} (after MET > 25)
    - N_{zveto} (after MET> 25 and Zveto cuts)
    - Subtract contribution from other processes
- Next use Monte Carlo:
  - to distribute the events in jets bins
    - N_0/N_{tot}, N_1/N_{tot}, $N_{\geq 2}/N_{tot}$
  - to move outside the mass window
    - $R^j_{o/i}$ = ratio of outside/inside for jet bin j
  - to calculate H_t cut efficiency (mass dependent)
    - Inside the mass window
    - Outside the mass window

DY background method 2

MC

Inside:

$$N^{j}_{DY}(in) = (N_j / N_{tot}) * N_{Zveto} * \varepsilon_{Ht}$$

DATA

Outside:

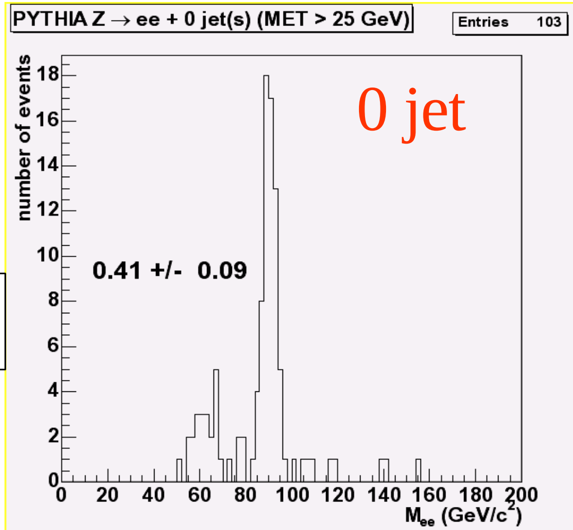
$$N^{j}_{DY}(o) = (N_j / N_{tot}) * R_{o/i} * N_{MET} * \varepsilon_{Ht}$$

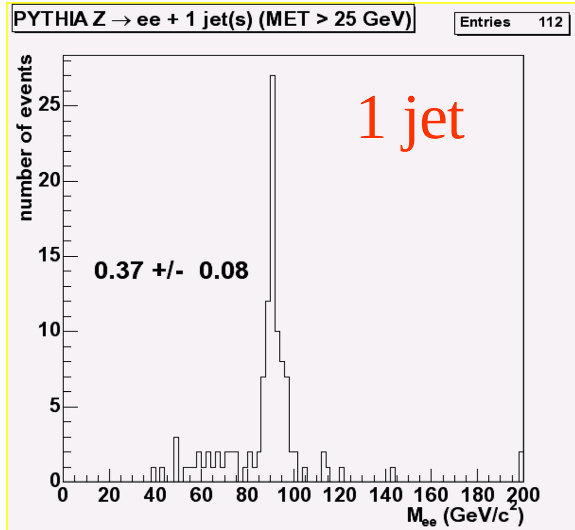
MC

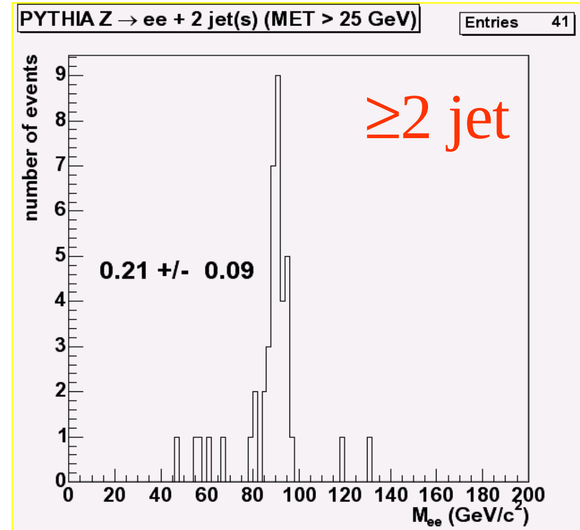
- We estimate DY in each jet bin j, where j=0,1, ≥2
- We want to check our predictions on 0 and 1 jet bin

Drell Yan:$R_{o/i}$

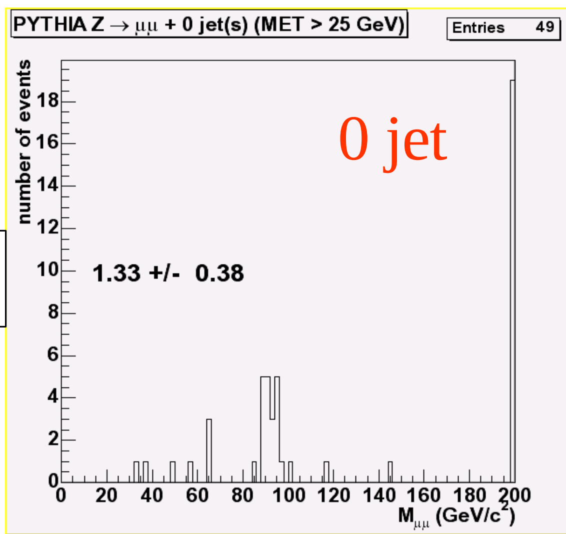
ee

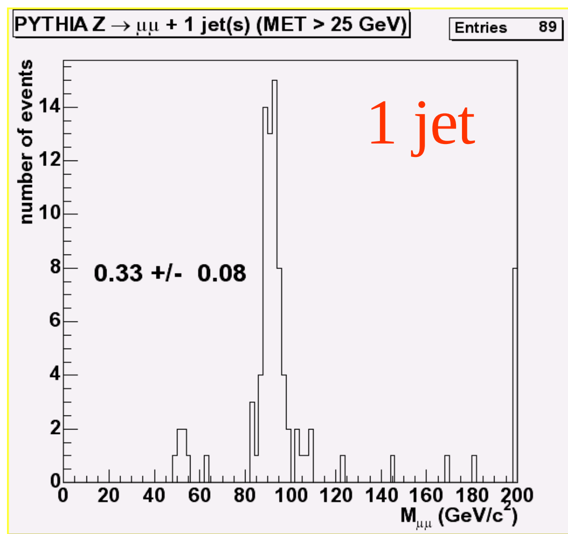


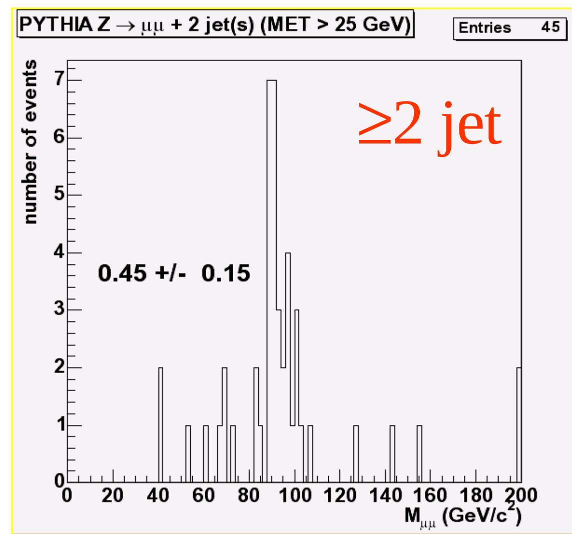




μμ

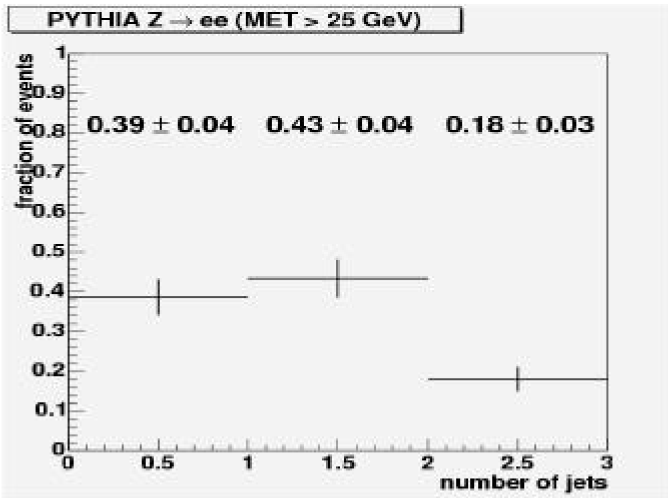


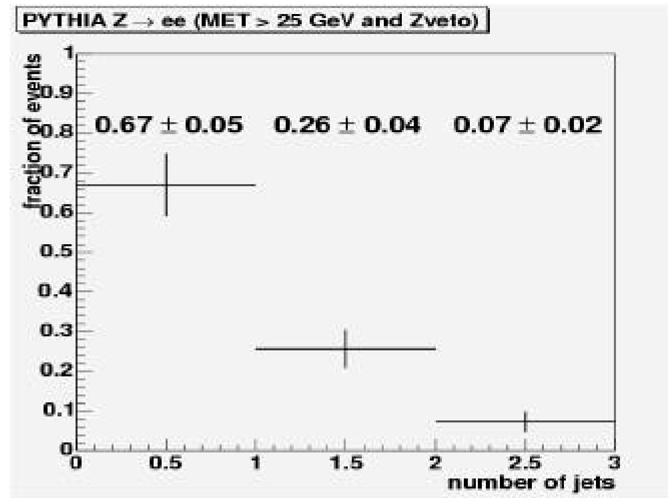




Drell Yan: N jet ratios

ee





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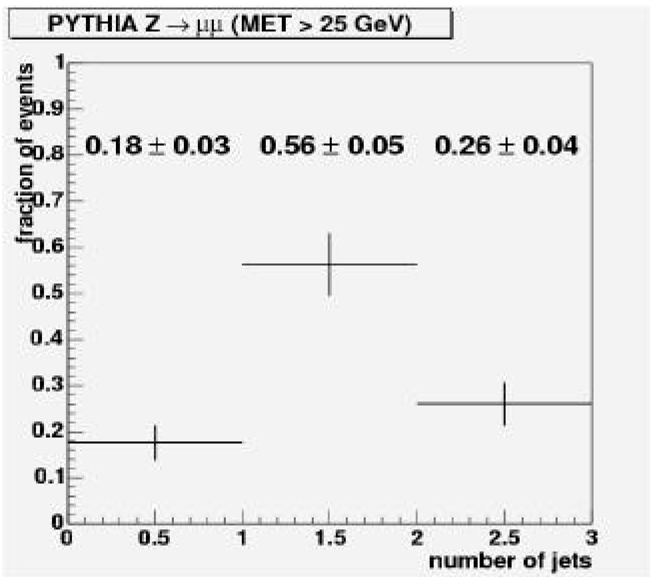
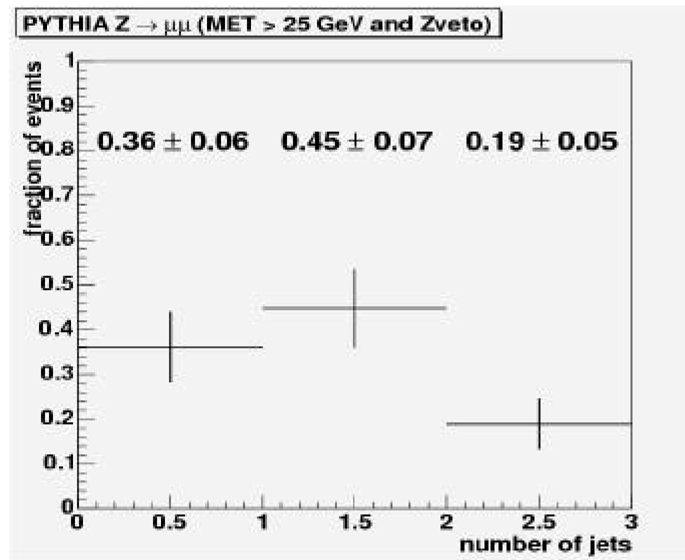
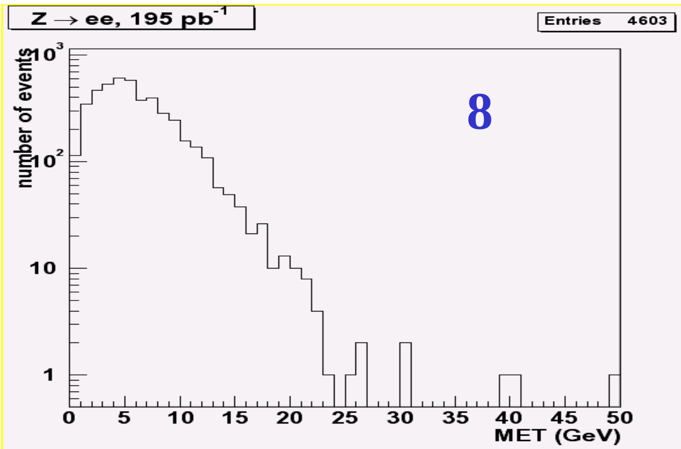
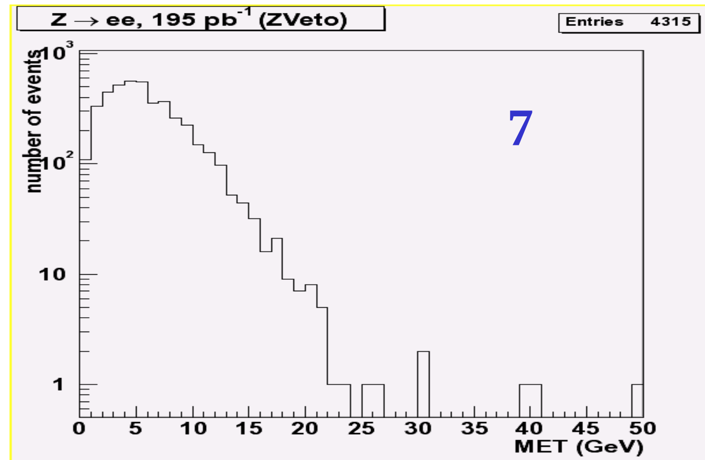


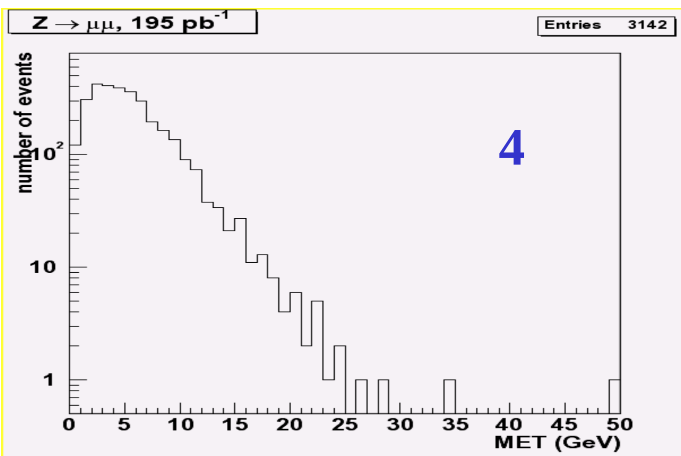


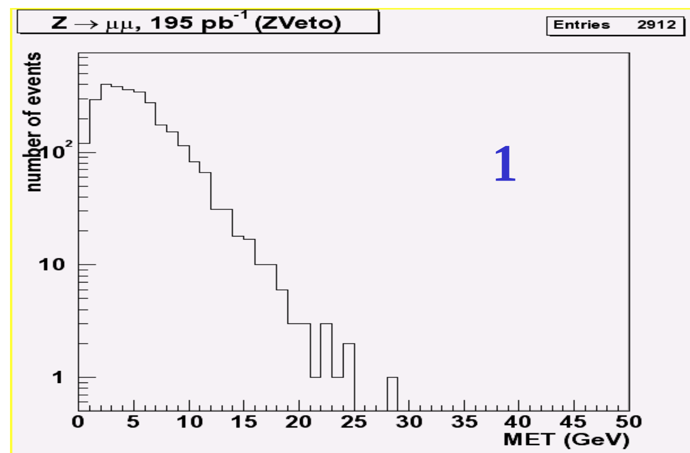
Drell Yan: N_{MET} and N_{Zveto}

- Dominant uncertainty is due to limited number of Z's after MET and Zveto cuts









Questions from Preblessing I

- Q: Where do your fake rates come from?
- A: For electrons:
  - Fake rate = (# fake electrons)/ (# CdfEmObjects)
- For muons:
  - Fake rate = (# fake muons)/ (# min ionizing tracks)
- Remember:
  - We parametrize the fake rates as a function of E_T and Isolation Fraction
  - We test the fake rates but using JET50 rates to predict JET20, JET70 and JET100 (See CDF 6742 for details)
    - Also look at b-enriched samples

N_{Jets}

For Blessing